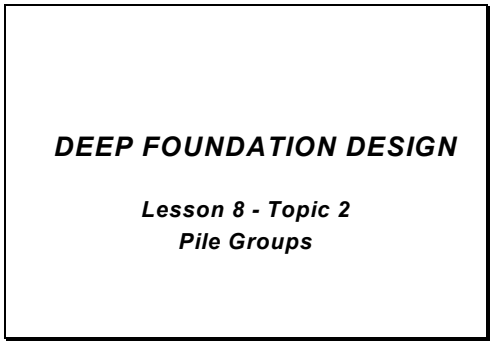
LESSON 8

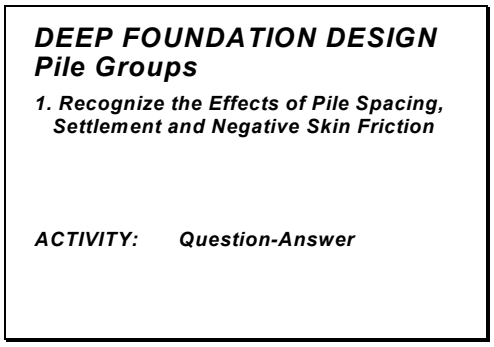
TOPIC 2

Deep Foundation Design – Pile Groups



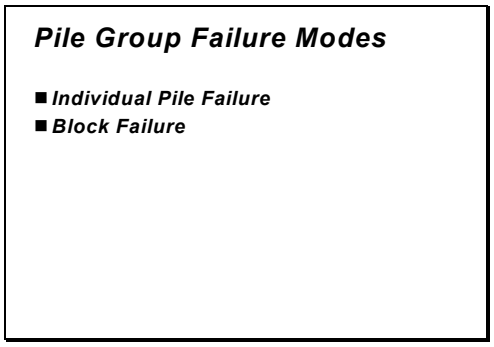
Slide 8-2-1

Header



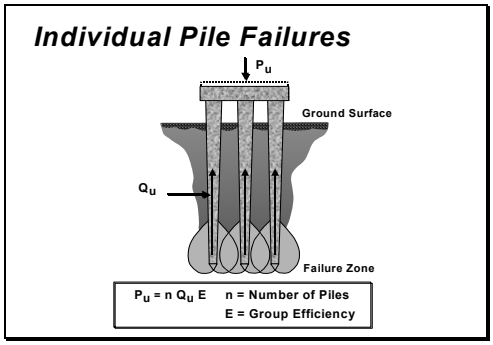
Slide 8-2-2

Objectives



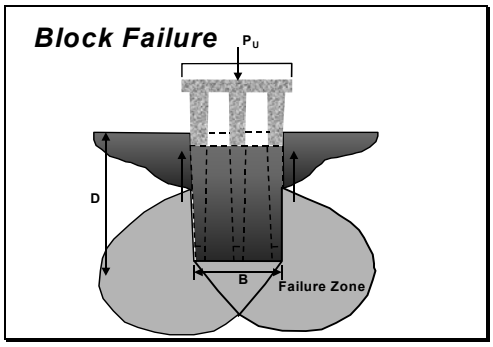
Slide 8-2-3

Introduce pile group behavior.



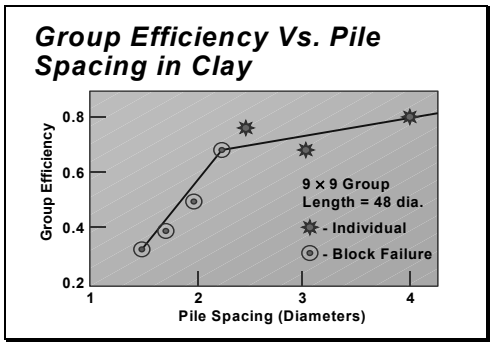
Slide 8-2-4

Explain the importance of pile spacing on the mode of pile failure. Begin with the case of individual pile failure as this is the only case considered for granular soils and the only practical case for cohesive soils. Note that the example we will use shows the pile cap out of the ground as the contribution of the pile cap to total pile group capacity is beyond the scope of this course. Then describe that the group fails by first mobilizing skin friction, then mobilizing the remainder of the end bearing until failure occurs. The skin and end bearing are both affected by the spacing of the piles in the group. In general as the spacing becomes closer, the capacity decreases. The relationship of the spacing and capacity is called the efficiency of the group and is denoted by the term, E. The group ultimate capacity is computed as the efficiency times the number of piles times the ultimate capacity of a single pile.



Slide 8-2-5

Continue the explanation of the importance of pile spacing on the mode of pile failure. Note that in cohesive soils when the piles are spaced too close (less than about 2.5 diameters center to center), the interior piles in the group cannot fully mobilize their capacity and capacity depends on the soil resistance around the periphery of the group. In this case the soil contained in between the piles will move down in a block fashion with the group. Such close spacing in cohesive soils should be avoided as block failure results in very low group capacity and pile efficiency. Block failures are uncommon as codes such as AASHTO restrict the center to center pile spacing to 3 diameters.



Slide 8-2-6

Reinforce the recommendation that close pile spacing in clay is to be avoided by showing this research on the reduction in efficiency.

Pile Group Capacity in Sand

- ***For general sand case use E = 100%***

$$P_{ult} = n\ Q_{ult}$$

Slide 8-2-7

Show equations for pile group capacity in sand. Note that research has shown that the efficiency can exceed 1.0 for closely spaced groups in sand due to densification. However efficiency values for design are suggested to be limited to 1.0.

Pile Group Capacity in Clay

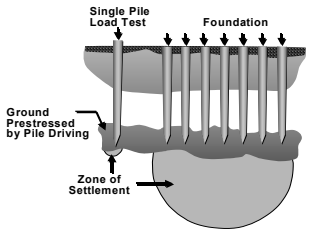
- ***For center to center pile spacing of 3D***
  - ***E = 70%***
- ***For center to center pile spacing of 6D***
  - ***E = 100%***

$$P_{ult} = n\ E\ Q_{ult}$$

Slide 8-2-8

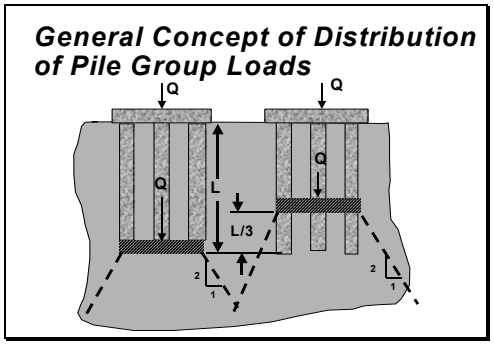
Show recommended equations for pile group capacity in clay and refer the students to standard specifications such as AASHTO for more information.

Settlement of Pile Groups in Sand (After Skempton)



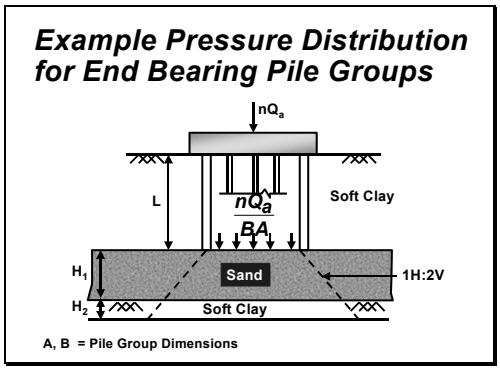
Slide 8-2-9

Introduce the concept of pile group settlement. Begin by noting that pile groups in granular soils cause little or no settlement unless the deposit is underlain by compressible soils. In that case the dimensions of the pile group become very important as the depth to which pressure is distributed is related to the group dimensions. Also note that the settlement results of a load test on a single pile which is tipped just above a soft deposit, may not be representative of the group settlement. This reinforces the need for an adequate subsurface investigation.



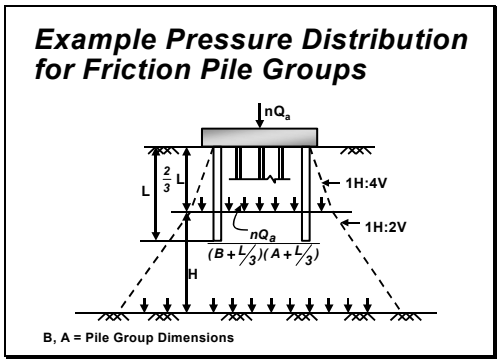
Slide 8-2-10

Show the computational process for pile settlement. Note that the general process is to assume that the group load is transferred to a fictitious footing located at either the pile tips for a predominately end bearing design or at the third point up from the tips for a predominately friction design.



Slide 8-2-11

Expand on the computational process for settlement of end bearing pile groups.



Slide 8-2-12

Expand on the computational process for settlement of friction pile groups. Note the need to find the appropriate dimensions of the fictitious footing by the procedure shown.

Settlement Magnitude

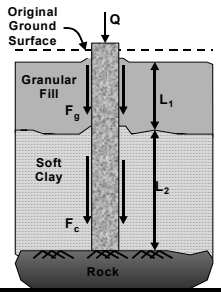
$$\Delta H = H \frac{C_c}{1+e_o} Log \frac{P_o + \Delta P}{P_o}$$

Where: ΔH = Settlement
H = Layer thickness
C_c = Compression Index
e_o = Initial voids ratio
P_O = Overburden Pressure
ΔP = Change in Pressure

Slide 8-2-13

Show the basic equation for computation of pile settlement. Mention that pile group settlement is usually smaller than the settlement for a typical footing located at ground surface. Ask the students to comment on which terms in the equation would cause a reduced settlement for the pile design (answer is H because the foundation usually reduces the thickness of compressible soils below the group; but more particularly the ratio of the log of the pressures. Note the value of Po is small at the ground surface and the ratio is large; but at depth the value of Po is large and the ratio small).

Negative Skin Friction



Slide 8-2-14

Introduce the concept of negative skin friction. Emphasize that the worst problems can occur at abutment locations where the piles are driven before the embankment settlement is complete.

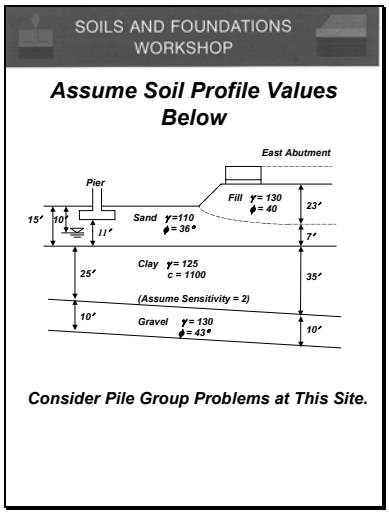
Slide 8-2-15

Show bitumen coating treatment and emphasize that this is only applied in the subsoil zone where drag is expected

Slide 8-2-16

Ask what is wrong in the picture.

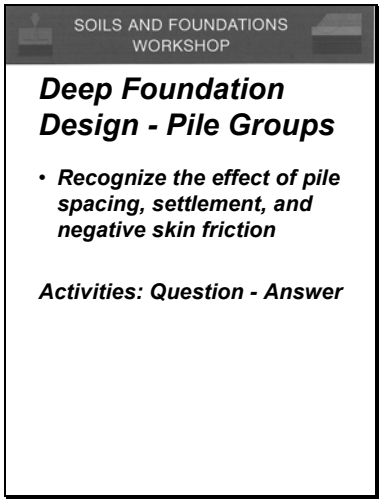
Answer is that the piles were driven upside down; the coated portion of the pile being driven into bearing layer and uncoated portion of the pile into the drag zone. Example of bad communication between design and construction.



Slide 8-2-17

Show Apple Freeway cross section and use to again test learning of deep foundation objectives.

Ask group what potential pile group problems can occur at this site (answer is negative skin friction unless a waiting period to the pile installation).



Slide 8-2-18

Repeat objectives for lesson 8 topic 2.